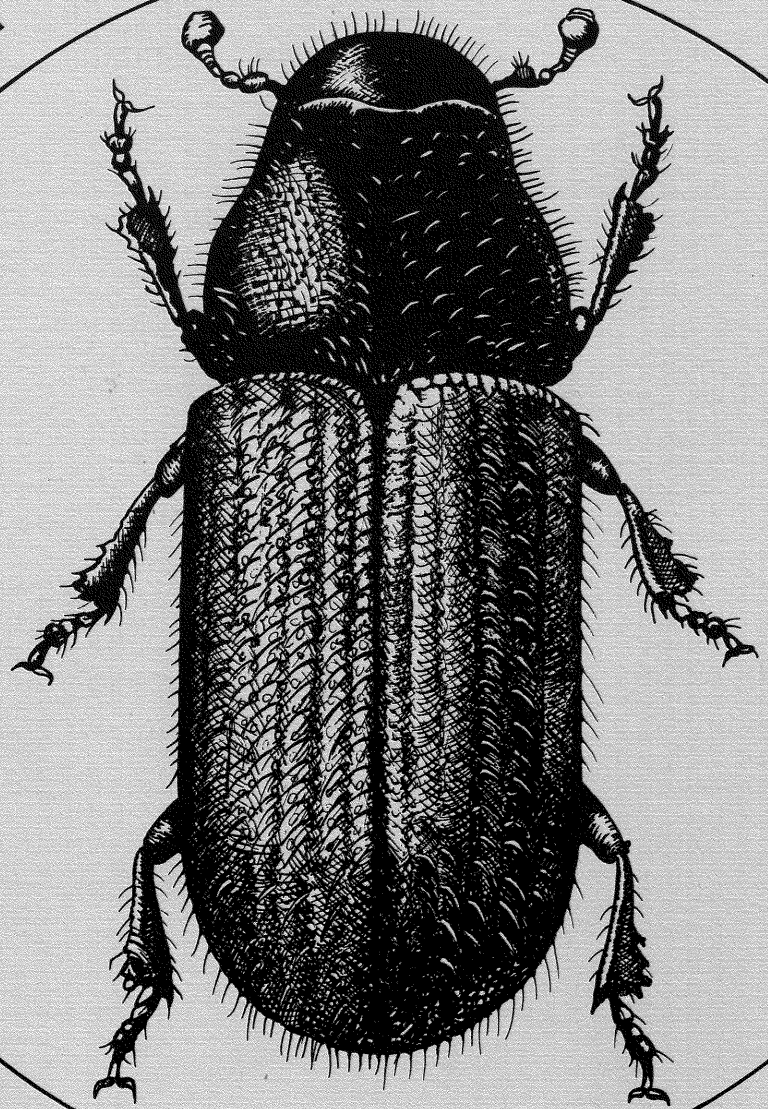


The Spruce Beetle in White Spruce Forests of Alaska

R. A. Werner
B. H. Baker
P. A. Rush



Abstract

This report provides information on the biological relationships between the spruce beetle and white spruce in Alaska. It is directed to forest managers, entomologists, and the general public who are concerned with managing the forest environment. The report presents problems associated with the spruce beetle and characteristics for identifying problem areas, and describes methods for preventing or suppressing beetle problems through proper forest management techniques.

KEYWORDS: Insect damage (-forest, insect damage control (forest), insect populations, management (forest), spruce beetle, *Dendroctonus rufipennis*, white spruce, *Picea glauca*, Alaska.

Authors

RICHARD A. WERNER is Research Entomologist, Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fairbanks, Alaska. BRUCE H. BAKER and PETER A. RUSH are Group Leader and Entomologist, respectively, Forest Insect and Disease Management, Division of State and Private Forestry, Forest Service, U.S. Department of Agriculture, Juneau, Alaska.

Contents

	Page
INTRODUCTION.	1
BEETLE DESCRIPTION AND LIFE CYCLE	2
Description of Beetle Life Stages.	2
Seasonal History and Development	2
BEETLE DAMAGE AND TREE LOSSES	4
Types of Spruce Material Infested.	4
Characteristics of Beetle-infested Trees . .	6
Beetle Impact on Spruce Stands	8
FOREST MANAGEMENT	10
Preventive Practices	10
Forest Stand Manipulation.	11
Sanitation and Salvage Cutting	11
Beetle Population Management	12
LITERATURE CITED.	12

Introduction

The purpose of this report is to familiarize the reader with the biology of the spruce beetle, the tree injury it causes, and various forest practices employed to reduce tree mortality and to salvage some benefits when trees are killed.

White spruce (*Picea glauca* (Moench) Voss) forests are subject to mortality from a variety of causes. Fires, windstorms, disease outbreaks, and insect infestations are some important events causing tree mortality. Of all the insects affecting white spruce, the spruce beetle (*Dendroctonus rufipennis* Kby.) has caused the most extensive mortality in Alaska's white spruce forests.

Periodically, spruce beetle populations increase rapidly; one such outbreak caused about 81 000 hectares (200,000 acres) of tree

mortality along the Copper and Chitina Rivers from approximately 1920 to 1930 (Downing 1957). Factors contributing to that outbreak are not known. In the early 1960's, spruce beetle populations on the Kenai Peninsula had built up in white spruce and closely related Lutz spruce (*P. lutzii* Little) (Downing 1961). Localized beetle activity increased; and by 1971, infestations covered about 105 300 hectares (260,000 acres), with losses estimated at a billion board feet (Curtis and Swanson 1972). In 1972, an additional outbreak was reported near Tyonek (fig. 1) (Baker and Curtis 1972). By 1975, the year of its decline, the outbreak had extended over a total of 115 130 hectares (284,370 acres^{1/}).

^{1/} Data on file with Forest Insect and Disease Management, Forest Service, U.S. Department of Agriculture, Juneau, Alaska.

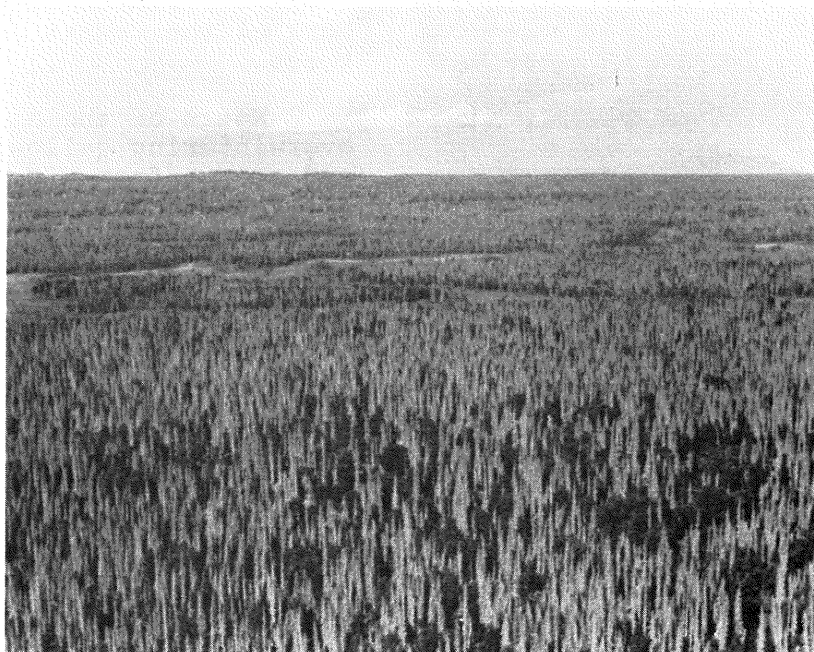


Figure 1.--White spruce-paper birch stand near Tyonek, Alaska. Light gray trees are spruce killed by spruce beetles.

Beetle Description and Life Cycle

DESCRIPTION OF BEETLE LIFE STAGES

The adult spruce beetle is dark brown to nearly black with reddish-brown wing covers (fig. 2) and is 4-7 mm (0.16-0.28 inch) long and 3 mm (0.12 inch) wide (Schmid and Beckwith 1975).

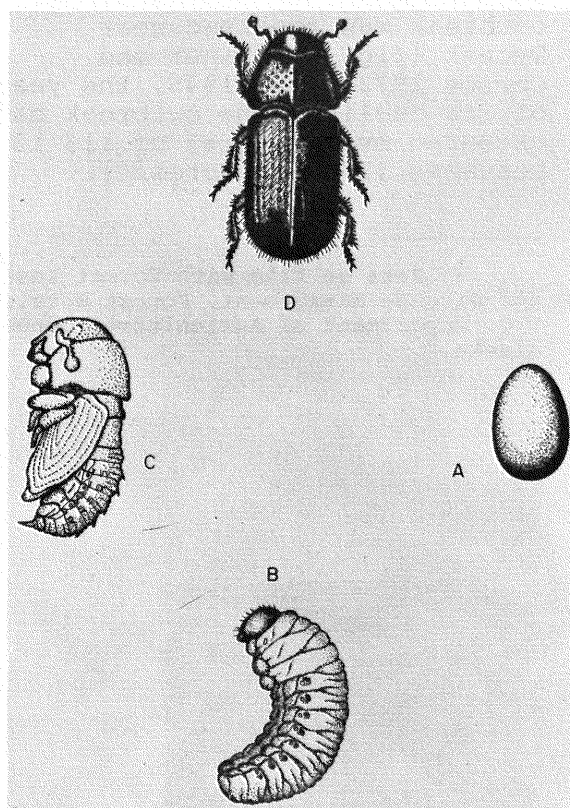


Figure 2.--Life stages of spruce beetle (A) egg, (B) larva, (C) pupa, and (D) adult.

Callow adults (those recently developed) range from pale yellowish to medium brown.

Eggs are pearly white, oblong, and 0.75-1.0 mm (0.03-0.04 inch) long. Larvae are stout, cylindrical, legless, and wrinkled with a pale tan head and creamy white body. A mature larva is 6-7 mm (0.24-0.28 inch) long (Grant and Cottrell 1968). Pupae are creamy white and become tan near maturity. They are 6 mm (0.24 inch) long with the legs, wings, and antennae fully visible.

SEASONAL HISTORY AND DEVELOPMENT

The development of the spruce beetle depends on climatic conditions, geographic area, and elevation. In most of Alaska, the spruce beetle has a 2-year life cycle in white spruce. Beetles overwinter mostly as adults or larvae in northern latitudes (Fairbanks area), with adults occupying pupal sites in the bark of the trunk or below snowline in the bark of the roots or base of infested trees. South of the Alaska Range (Anchorage area), an equal number of larvae can be found overwintering under the bark of the trunks of standing trees.

North of the Alaska Range, overwintering callow adults mature and emerge from mid-May through July; whereas in south-central Alaska, adults emerge from early June through mid-July (Beckwith 1972). The newly emerged adults attack fresh host material such as windfall, freshly cut logs or injured trees, slash, and even standing, healthy trees. Overwintering larvae mature into adults during the spring months and emerge and attack in late summer. Some adults that make their initial attack in late summer may overwinter and make a second attack the following spring (Grant and Cottrell 1968).

Upon finding a suitable host, the female beetle bores through the bark into the phloem area, i.e., the area between the outer bark and the wood, and starts to construct an egg gallery, scoring the xylem (wood) slightly in the process (fig. 3). The male then enters the gallery, probably attracted there by chemical odors produced by the host tree and the female beetle; and there mating takes place. The egg gallery is constructed parallel to the wood grain and usually upward from the entrance hole in standing trees (fig. 4). The galleries are slightly wider than the beetle and are 6-30 cm (2.4-12 inches) long (Schmid and Beckwith 1975). Eggs are laid in groups on either side of the egg gallery.



Figure 3.--Spruce tree with section of bark removed to show beetle galleries scored in xylem (wood) of tree trunk.

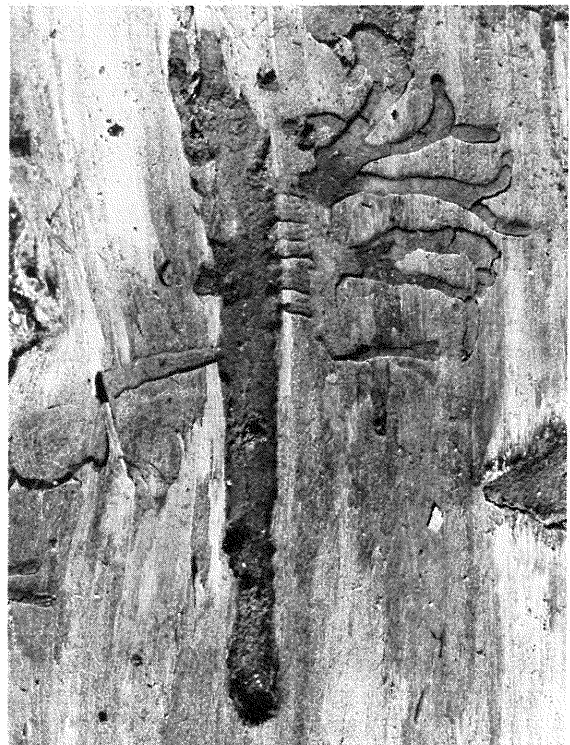
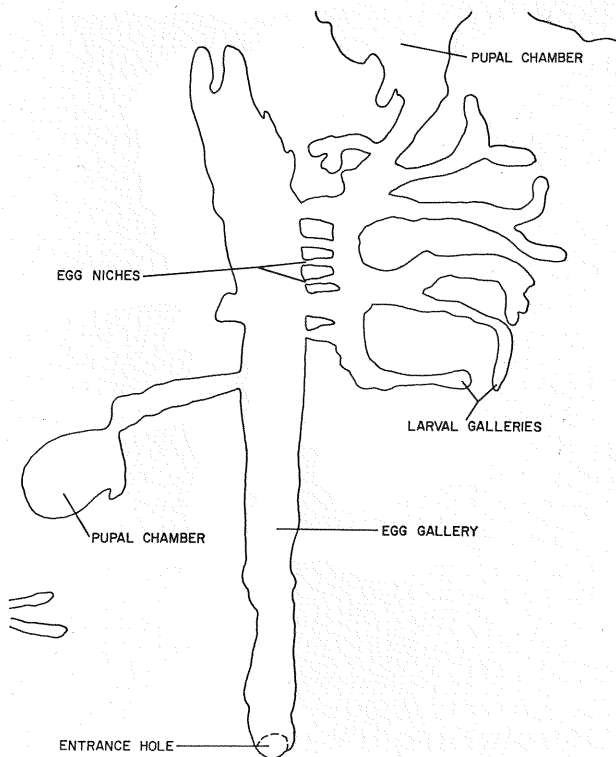


Figure 4.--Spruce beetle egg gallery in phloem of white spruce tree (parallel to grain). Galleries across grain are made by newly hatched larvae.

The number of eggs laid varies from 4 to 14 per cm (0.4 inch) of gallery. Parent beetles that survive may then re-emerge, attack, and establish a second brood or overwinter in the original host tree and re-emerge and attack the following spring. The eggs from early summer-emerging beetles usually hatch in 3-4 weeks, and develop into mature larvae which overwinter and develop into pupae and adults the following spring.

Newly hatched larvae bore at right angle from the longitudinal egg gallery and feed in clusters in the phloem. Larvae begin to form individual feeding galleries when they are about one-third grown. In south-central Alaska, many larvae develop into pupae and adults in the late summer; and the insect may overwinter as callow and/or parent adults. Before the larvae are fully mature, they excavate a shallow cell in which they form into pupae (fig. 5); however, some of the mature larvae bore into the inner bark where they excavate pupal cells.

Beetle Damage and Tree Losses

TYPES OF SPRUCE MATERIAL INFESTED

The previously mentioned large outbreaks have occurred in an area of Alaska lying between the moisture-laden maritime zone, where white spruce yields to Sitka spruce (*P. sitchensis* (Bong.) (Carr.)), and the continental zone of the interior, where the spruce beetle is common but where extensive outbreaks had not been recorded as of 1976. These



Figure 5.--Spruce beetle pupae in pupal chambers at end of larval galleries.

outbreaks also occurred in spruce forests containing many large diameter trees; and recent outbreaks in the Cook Inlet basin were associated with warm, dry summers in 1968 and 1969 and accumulations of spruce debris resulting from forest clearing (Crosby and Curtis 1970). Spruce slash, cull logs, stumps, or windthrown trees are highly productive breeding sites for the insect (Massey and Wygant 1954, Dyer and Taylor 1971) (fig. 6). When populations increase and sufficient down material is no longer available to absorb the population, beetles



Figure 6.--Windthrown trees and logging slash are highly susceptible breeding sites for spruce beetles.



Figure 7.--Boring dust excavated from the bark and phloem by adult beetles.



Figure 8.--Boring dust produced by carpenter ants in the trunk of a spruce tree.



Figure 9.--Resin tube is external evidence that beetles are or have been attacking the tree.

infest nearby living trees, particularly in mature stands and during warm, dry summers (Schmid and Beckwith 1975).

CHARACTERISTICS OF BEETLE-INFESTED TREES

The first indication of beetle attack is reddish-brown boring dust deposited at the beetles' entrance holes, in bark crevices, and on the ground around the trunk of the infested tree (fig. 7). A close examination of the tree to detect these indicators is necessary, particularly in the early stages of attack or on cloudy days when light intensity is reduced. Boring dust produced by carpenter ants and wood boring beetles can be distinguished from that of the spruce beetle by its light yellowish color (fig. 8). Globules of resin (pitch tubes) located on the tree trunk are additional evidence of beetle attack (fig. 9).

Experience with spruce beetles in Engelmann spruce (*Picea engelmannii* Parry) indicates that infestation intensity depends on tree size, age, and basal area, percentage of spruce in the canopy, and physiographic location (exposure and elevation of site) (Schmid and Frye 1976). Some trees overcome beetle attack by exuding a heavy flow of resin which fills the beetle galleries and entrance holes and traps the beetles. The success of such trees to overcome attack depends on the number of beetles attacking the tree, the rate of attack, and the vigor of the tree. Trees that repel beetles contain resin tubes that are usually whitish in color; but if beetles continue boring, the resin tubes become

mixed with boring dust and frass (beetle feces) and appear reddish-brown. Less vigorous trees or trees attacked late in the summer often produce few or no resin tubes when under attack; however resin tubes and resin flow, in general, are poor criteria for distinguishing beetle attack because uninfested trees sometimes exhibit resin flow on the bark due to abnormal physiological conditions or sapsucker damage.

After the tree has been infested and the phloem girdled by beetle galleries, the needles turn yellowish-green (begin to fade) and may remain that color throughout the winter following attack of the previous summer. Within 2 years after the initial attack, needles may fall (fig. 10)



Figure 10.--Spruce trees killed by beetles appear lighter in color than healthy trees.

and the trees frequently appear reddish-brown due to the color of exposed twigs. Trees with reddish-brown crowns usually no longer contain spruce beetles. Sometimes trees may be infested with beetles on only one side and will appear faded green or even normal in color. This is known as a "strip attack" because unsuccessful attacks are sustained on only one side of the tree, usually on less than one-half of the circumference. The tree retains a continuous strip of live cambium from the top down to the roots. These trees do not appear discolored but have the other external symptoms of beetle attack such as boring dust and, sometimes, resin tubes on the infested portion. The degree of discoloration of infested trees may be associated with the amount of soil moisture prior to and during beetle attack, humidity, exposure, site, elevation, tree vigor, root disease, or intensity and success of attack.

Discolored or faded trees are commonly found that have not been attacked by beetles. The causes of this particular discoloration could be attributed to several factors: lack of proper nutrients, inadequate moisture, site condition, diseases, air pollutants, or some unknown physiological malfunction of the tree.

Beetle-infested trees are prime feeding sites for woodpeckers, and bark removed by the pecking activity can be found scattered around the base of most infested trees (fig. 11).



Figure 11.--Beetle-infested white spruce trees showing patches of bark removed by woodpeckers in search of beetles (left) and bark debris caused by woodpecker activity (right).

BEETLE IMPACT ON SPRUCE STANDS

Increases in spruce beetle populations and subsequent losses to white spruce stands depend on: (1) climatic and seasonal weather conditions, (2) physiographic location of spruce stands, (3) stand composition, (4) natural mortality factors of the beetle, and (5) disturbance of the spruce stand which results in an abundance of spruce debris. Combinations of the above factors result in unusually high tree losses.

Large, mature white spruce stands are highly susceptible to spruce beetle attack (Baker and Kemperman 1974), and such stands are typical of interior and south-central Alaska (fig. 12). High populations of the spruce beetle are quite capable of modifying stand age class and species composition as reported by Baker and Kemperman (1974) for south-central Alaska. They examined a white spruce-paper birch forest that consisted of 77 percent white spruce and 22 percent paper birch prior to



Figure 12.--Typical mature white spruce stand in interior Alaska.

infestation by spruce beetles. At the end of the outbreak, 65 percent of the spruce 12.7-cm (5-inch) d.b.h.^{2/} and larger had been killed. The incidence of tree mortality was directly proportional to tree size class (fig. 13). The average age of surviving dominant and codominant spruce was 142 years, but ages ranged from 75 to over 230 years. Spruce regeneration was sparse in the infested stand. There was an average of 11 spruce saplings^{3/} per hectare (28 per acre); the range was 0-77 per hectare (0-192 per acre) on sample plots. Spruce seedlings^{4/} ranged from 0 to 680 per hectare (0-1,700 per acre) on sample plots. Deciduous competition to spruce includes birch, rusty menziesia, currant, ferns, and

other species. This type of residual vegetation can make future stand composition of spruce uncertain.

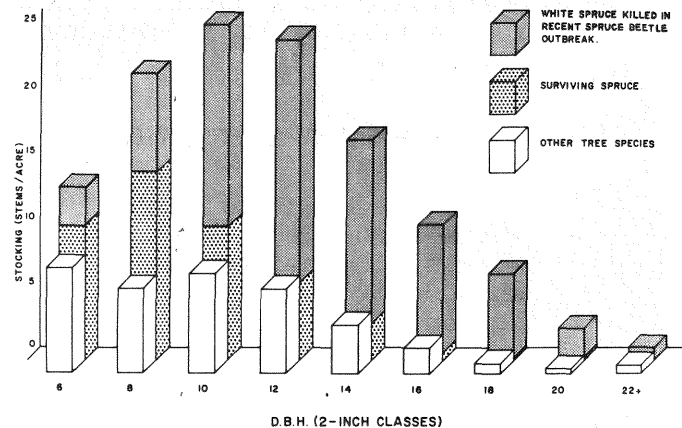


Figure 13.--Effect of beetle-caused mortality on stand composition. Other species consist of 22.0-percent paper birch and 1.2-percent balsam poplar and mountain hemlock.

^{2/} Diameter breast height.

^{3/} Saplings, 2.5- to 12.7-cm (1- to 5-inch) d.b.h.

^{4/} Seedlings, 2.5-cm (1 inch) to less than 1.3 m (4.5 feet) in height.

It is important to realize that the previously mentioned losses are unusually high and that the surviving spruce components of other residual stands may be considerably higher. The above is an example of what can occur rather than what necessarily will occur. However, it is not uncommon for a spruce beetle outbreak to continue until most large spruce have been killed. A forest with an abundance of large, mature white spruce is prerequisite to beetle outbreaks if combinations of the forementioned factors are present. Such a stand remains susceptible to the beetle unless forest composition is altered by fire, harvest, extensive windthrow, or the beetles themselves.

Once mortality is quantified, various economic yardsticks can be used to determine actual monetary losses or, in some cases, benefits. An example of a loss is timber inventory destroyed; a benefit would be an increase in browse plants where moose habitat management is a high priority, or the conversion of a conifer forest into a more desirable hardwood forest.

Forest Management

Management of Alaska's white spruce forests to reduce losses from spruce beetles should involve the following actions: (1) specific preventive forest practices, (2) forest stand manipulation, (3) salvage logging to prevent economic losses in infested areas, and (4) beetle population management.

PREVENTIVE PRACTICES

One means of preventing spruce beetle outbreaks is to avoid creating forest conditions which are conducive to the buildup of beetle populations (fig. 14). Preventing the accumulation of felled spruce material greater than 15.2-cm (6-inch) diameter (fig. 15) will



Figure 14.--Forest clearing without proper slash disposal.



Figure 15.--Forest clearing following slash disposal by burning.

preclude beetles from multiplying in down material and subsequently infesting healthy trees. Windstorms can cause the same result, although they occur infrequently and their occurrence is usually beyond man's control.

Spruce debris over 15.2-cm (6-inch) diameter, from man-caused activities in the forest, should be properly handled before beetle emergence. Proper handling can consist of utilization, burning, burying, or some other method that destroys the developing insects, disrupts their development, or denies their access to host material. Avoid damaging tree trunks and root systems so beetles will not be attracted to these weakened trees. Care should be taken to avoid (1) scarring trunks with equipment, (2) severing roots in road and drainage activities, (3) altering drainage patterns around root systems by cut and fill operations, and (4) severely compacting soil.

FOREST STAND MANIPULATION

Forest stand structure and species composition can be variously altered to reduce susceptibility to beetle outbreaks. The key is to maintain a stand that does not consist of numerous large, overmature spruce. Thinning, shelterwood harvesting, clearcutting, fire, and even the beetle itself can create a forest with fewer large spruce than would otherwise exist. Clearcuts provide maximum sunlight for felled logs, and beetles cannot survive high temperatures generated by direct sunlight. On the other hand, clearcutting large areas can create forest edges that are highly susceptible to blowdown. Size and location of

timber sale are important in creating spruce stands that can withstand high winds.

Long-term timber management goals should emphasize harvesting older stands and establishing a rotation age of 100 years. Simultaneous outbreaks over large areas, as in the Tyonek and Kenai outbreaks, can be prevented by planning a mosaic of forests of different age classes. Young stands of spruce are less susceptible to beetle infestation than are mature stands, and mixed stands of spruce and hardwoods will not suffer the losses that pure spruce stands will suffer given trees of comparable diameter size.

In some situations where a localized yet troublesome population of spruce beetles is active, trees can be felled and purposely left temporarily to attract and concentrate beetles (Schmid and Beckwith 1975). After beetles have entered downed trees or logs, they can be destroyed through wood utilization, burning, or chemical application.

SANITATION AND SALVAGE CUTTING

Sanitation cutting involves the felling of beetle-infested trees in a stand and destruction of the beetles prior to their emergence. This method can be an effective means of preventing the spread of newly developed and fairly localized infestations in Alaska's white spruce stands. The success of sanitation cutting depends on periodic surveys throughout the summer in order to detect beetle brood trees. This method is somewhat costly because helicopters may be required to transport suppression crews to remote beetle-infested areas. Infested trees that are

felled can be utilized, if accessible, or burned in isolated areas where other methods of destroying the beetle population are impractical.

Salvage utilization is not a method for reducing beetle populations but is used primarily to reduce losses inflicted by large beetle outbreaks. Beetle-killed trees yield good fiber for a considerable number of years. Although the potential for use as dimension lumber may begin to decline soon after a tree is infested, the potential for pulp is far more lasting. Tree deterioration and pulping data for south-central Alaska's white spruce have shown that beetle-killed spruce dead for 50 years produced kraft pulps of premium quality in strength and brightness.^{5/}

BEETLE POPULATION MANAGEMENT

The following discussion is concerned primarily with methods and techniques that deal directly with the insect.

Preventing the occurrence of an insect problem is obviously better than suppressing one after populations have increased. Prevention of beetle population increases by biological means is the most desirable approach but presently is limited to a few proven techniques. Most are still in the developmental stages.

One such technique is the use of behavioral chemicals such

as aggregation attractants and antiattractants. Attractants are used to trap beetles which aggregate to the source whereas antiattractants disrupt normal aggregation and mating patterns and prevent buildup of beetle populations. The use of anti-attractants to suppress initial outbreaks of spruce beetle activity in Alaska has shown promise (Furniss et al. 1976).

Future developments and refinements in the use of behavioral chemicals to suppress beetle activity will provide the land manager with additional prevention and suppression techniques; however, the best beetle control is prevention through proper forest management.

Literature Cited

- Baker, Bruce H., and Donald J. Curtis.
1972. Forest insect and disease conditions in Alaska-1972. USDA For. Serv., Alaska Region. 9 p.
- Baker, Bruce H., and Jerry A. Kemperman.
1974. Spruce beetle effects on a white spruce stand in Alaska. J. For. 72(7):423-25.
- Beckwith, Roy C.
1972. Scolytid flight in white spruce stands in Alaska. Can. Entomol. 104(12):1977-83.
- Crosby, David, and Donald J. Curtis.
1970. Forest insect and disease conditions in Alaska during 1969. USDA For. Serv., Alaska Region. 15 p.
- Curtis, Donald J., and Carl W. Swanson.
1972. Forest insect and disease conditions, Alaska Region-1971. USDA For. Serv., Alaska Region. 17 p.

^{5/} Data on file at Institute of Northern Forestry, Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fairbanks, Alaska.

- Downing, G. L.
1957. The recent history of destructive forest insect activity in Alaska. Proc. 8th Alaska Sci. Conf., Anchorage, Alaska. 6 p.
- Downing, George L.
1961. Conditions of forest insects in forest regions, Alaska. In Forest Insect Conditions in the United States, 1960. USDA For. Serv. 20 p.
- Dyer, E. D. A., and D. W. Taylor.
1971. Spruce beetle brood production in logging slash and windthrown trees in British Columbia. Pac. For. Res. Cent. Inf. Rep. BS-X-62. Can. For. Serv., Victoria, B.C.
- Furniss, Malcolm M., Bruce H. Baker, and Bruce B. Hostetler.
1976. Aggregation of spruce beetles (Coleoptera) to seudenol and repression of attraction by methylcyclohexenone in Alaska. Can. Entomol. 108(12): 1297-1302.
- Grant, J., and C. B. Cottrell.
1968. Spruce beetles in British Columbia. For. Res. Cent. For. Pest Leaflet No. 13, For. Insect and Dis. Surv., Can. For. Serv., Victoria, B.C. 7 p.
- Massey, C. L., and N. D. Wygant.
1954. Biology and control of the Engelmann spruce beetle in Colorado. USDA For. Serv. Circ. 944. 35 p.
- Schmid, J. M., and Roy C. Beckwith.
1975. The spruce beetle. USDA For. Serv. For. Pest Leaflet 127. 7 p.
- Schmid, J. M., and R. H. Frye.
1976. Stand ratings for spruce beetles. USDA For. Serv. Res. Note RM-309, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

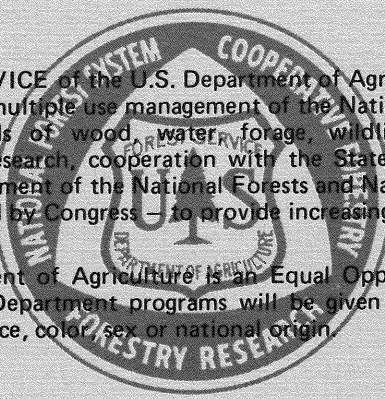
Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

Fairbanks, Alaska	Portland, Oregon
Juneau, Alaska	Olympia, Washington
Bend, Oregon	Seattle, Washington
Corvallis, Oregon	Wenatchee, Washington
La Grande, Oregon	

*Mailing address: Pacific Northwest Forest and Range
Experiment Station
P.O. Box 3141
Portland, Oregon 97208*

The seal of the U.S. Forest Service is a circular emblem. It features a central shield with a stylized tree and the letters 'U.S.' above it. The shield is surrounded by a circular border containing the text 'FOREST SERVICE' at the top, 'DEPARTMENT OF AGRICULTURE' at the bottom, and 'FORESTRY RESEARCH' on the sides. The words 'SYSTEM' and 'COOPERATION' are also visible on the left and right sides of the border.

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture is an Equal Opportunity Employer. Applicants for all Department programs will be given equal consideration without regard to race, color, sex or national origin.